REMARKS

Applicant has amended claims 1-9, 11, and 13-15; cancelled claims 10 and 12; and added new claims 16 and 17. Claims 1-9, 11, 13-15 and 16-17 are pending in this application and are in condition for allowance, which is respectfully requested.

Claims 4 and 15 stand rejected under 35 U.S.C. §112. Claim 4, as amended, relates claim 1 elements to the radial (r) direction according to the equation where $r^2=x^2 + z^2$. Claim 15, as amended, relates claim 13 elements of a pair of distributed Bragg reflector mirrors forming a vertical waveguide common to component devices in the photonic integrated circuit and the waveguide is integral to said pair of distributed Bragg reflector mirrors. Applicant's amendments correct the informalities and place claims 4 and 15 in condition for allowance, which is respectfully requested.

Claims 1-3, 7, 8, and 11-15 stand rejected under 35 U.S.C. §102(e) on the basis of Abeles (U.S. Pat. No. 6,445,724). Applicant's traverse the rejection because all of the independent claims have been amended to recite, among other things, a distributed feedback grating made an integral element of the laser cavity. For clarity, claim 1 has been amended to recite a discrete standing wave photonic device, claim 7 has been amended to recite a discrete traveling wave photonic device, and claim 13 has been amended to recite a photonic integrated circuit. Support for these amendments is found, for example, on pages 4, 19-20, 29, 31-33, 36, 42-44, 50 and 66, and separate sections beginning on pages 15 and 54 of the specification. Other claim amendments are unrelated to patentability over the cited references.

For this reason alone, claims 1, 7 and 13 are patentable over the reference. As a result, claims 4-6, 8, 9, 11, and 14-16, dependent from claims 1, 7 and or 13 are also allowable over the art of record. Withdrawal is requested.

Claim 1 has been amended to provide for:

> "a discrete standing wave photonic device
>
> a pair of distributed Bragg reflector mirrors surrounding a cavity in a vertical (y) direction, whereby said cavity forms a vertical waveguide;" and
>
> "a distributed feedback grating in a longitudinal (z) direction integral to said cavity in said vertical (y) direction."

Support for the DFB grating in a discrete standing wave device of the present invention is found on pages 4, 19-20, 29, 31-33, 36, 42-44. As a result, the DFB grating of the current invention 1) lies within the cavity, 2) helps to determine the wavelength and 3) is intended to provide a DFB grating to the cavity.

Regarding Claim 1, Abeles (US 6,445,724) describes an integrated laser device whereas the present invention describes a discrete standing wave device. Abeles' discloses a distributed feedback (DFB) grating (FIG. 4, element 352) in the longitudinal direction (z) that lies outside of the vertical laser cavity and is intended to redirect the output power of said vertical cavity laser. Therefore, it is not an integral element of the laser cavity and does not provide the feedback necessary to support an optical mode. As a result, it does not help determine the lasing wavelength. Second, the purpose of the grating Abeles DFB redirect the output power of his vertical cavity laser; he teaches to suppress feedback from the expansion region and beyond by introducing an optional isolation layer

350. *See* Col. 5,ll. 56-61. As a result, Abeles' DFB grating (element 352) 1) lies outside the laser cavity, 2) does not help to determine the lasing wavelength and 3) is intended to suppress, not provide, feedback to said cavity.

Moreover, the present claim amendments avoid the Abeles reference because Abeles discloses and teaches an integration scheme whereby a conventional vertical cavity laser and a vertical cavity amplifier can be integrated via out-of-plane, surface gratings (also of 2nd order) and surface waveguides. There are multiple disadvantages to this approach. For example, any 2nd order gratings are extremely inefficient at coupling light at right angles, thereby placing large demands on the performance of the amplifier to compensate for these inefficiencies. Furthermore, the gratings are inherently bi-directional so as to subject the master oscillator (VCL) to large amounts of feedback. Finally, light must be removed from the side of the substrate opposite the waveguide requiring complex fabrication steps to achieve. In summary, Abeles' DFB grating (element 352) 1) lies outside the laser cavity, 2) does not help to determine the lasing wavelength and 3) is intended to suppress, not provide, feedback to said cavity. As above, the DFB grating of the current invention 1) lies within the laser cavity, 2) helps to determine the lasing wavelength and 3) is intended to provide feedback to said cavity (while referred to by a common name ("grating"), the form and function of these elements is completely different). Applicant believes claim 1 overcomes Abeles and is in condition for allowance, which is respectfully requested.

Claim 7 has been amended to provide for:

"A discrete traveling wave photonic device; and

a pair of distributed Bragg reflector mirrors surrounding a cavity in the vertical (y) direction, whereby said cavity forms a vertical waveguide;"

Support for the DBR mirrors in a discrete traveling wave device of the present invention is found on pages 4, 19-20, 29, 31-33, 36, 42-44. The present invention makes a waveguide that 1) uses DBR mirrors to form the cladding layers (referred to in the specification as *effective cladding layers*), 2) is formed within the active plane of the device, and 3) does not require coupling by bending of the light. As a result, Claim 7 of the present invention now provides for a discrete photonic device for a traveling wave wherein "said cavity forms a vertical waveguide" or otherwise a distributed Bragg reflector (DBR) waveguide for a traveling wave.

Similarly, claim 13 has been amended to provide for a photonic integrated circuit, comprising:

"a pair of distributed Bragg reflector mirrors surrounding a cavity in a vertical (y) direction, whereby said cavity forms a vertical waveguide common to component devices in the photonic integrated circuit; and

optical tap means for injecting or extracting light from said waveguide_integral to said pair of distributed Bragg reflector mirrors"

The component devices can be a combination of component devices including the discrete standing wave photonic device of claim 1 and the discrete traveling wave photonic device of claim 7, as set forth in new claim 17.

Abeles does not suggest, teach or disclose a DBR waveguide for a traveling wave. Abeles uses its Bragg reflectors for the laser and amplifier sections of his integrated semiconductor laser. For, example, Abeles discloses a waveguide wherein the cladding layers comprise single, homogeneous material layers; unlike the present invention that

forms waveguide from DBR mirrors. Moreover, Abeles discloses an integrated semiconductor laser wherein the distinct elements of the laser are connected via 90° bends in the path of the propagating light. For example, the waveguide cited by the examiner (FIG.4, element 302) lies outside the active plane of the device and must be connected by a 90° bend; Applicant incorporates the arguments regarding claim 3 below in response. Abeles, in fact, teaches away from the <u>forming</u> the combination DBR mirrors, a waveguide in the lateral direction, and no optical confinement in the longitudinal direction because these elements are expressly separated in FIG. 4. Due to Abeles' placement of the waveguide, the means of lateral optical confinement is limited to real index guiding (via material regrowth) and effective index guiding (such as via a rib or ridge waveguide). Abeles does <u>not</u> suggest, teach or disclose a fundamental novelty here is to use the DBR mirrors are used to *form* a DBR waveguide for a traveling wave utilizing the waveguide cladding layers in the vertical (y) direction.

In sharp contrast, the present invention makes a waveguide that 1) uses DBR mirrors to form the cladding layers (referred to in the specification as *effective cladding layers*), 2) is formed within the active plane of the device, and 3) does not require coupling by bending of the light. The waveguide of the present invention can be formed by gain/loss modulation and/or resonant wavelength modulation <u>in addition to</u> index modulation and effective index modulation. The current invention can be configured for a passive waveguide having a significant portion of at least one cladding layer comprised of a DBR mirror, or in alternative embodiments, both cladding layers can be configured as DBR mirrors. Given the fundamentally different and novel nature of the active waveguide

(cladding material, placement, and coupling), all potential means of forming the lateral (x) waveguide should be allowed. Applicant believes claim 7 overcomes Abeles and is in condition for allowance, which is respectfully requested.

Similarly, Applicant believes claim 13 overcomes Abeles for the above reasons stated for allowance of claims 1 and 7. Abeles does not show, teach or suggest the forming a vertical waveguide common to component devices in the photonic integrated circuit. Moreover, Abeles does not show, teach or suggest optical tap means for injecting or extracting light from the common waveguide integral to the pair of distributed Bragg reflector mirrors. Applicant believes claim 13 overcomes Abeles and is in condition for allowance, which is respectfully requested

With respect to dependent claim 2, the specification provides the optical tap as "a section of waveguide where either top or bottom cladding comprised of a DBR mirror is of sufficiently reduced reflectivity, as compared to the immediately adjacent waveguide, so as to allow a significantly greater [a factor of two or more] amount of light to escape from said cladding." *See* page 28. Abeles optical tap (FIG. 4, element 351) has 1) waveguide cladding layers that do not comprise DBR mirrors, and 2) the reflectivity of the optical output is the same as that of the surrounding material (99.5%). No layers are removed from, nor AR coatings applied to the "optical tap" as in the current specification. *See* page 28. Applicant believes claim 2 overcomes Abeles and is in condition for allowance, which is respectfully requested.

With respect to dependent claim 3, Abeles discloses a waveguide wherein the cladding layers comprise single, homogeneous material layers. This is in contrast to the

current invention wherein part of the fundamental novelty is that the active waveguide comprises DBR mirrors. Further, Abeles discloses an integrated semiconductor laser wherein the distinct elements of the laser are connected via 90° bends in the path of the propagating light. For example, the waveguide referred to in the current office action (FIG. 4, element 302) lies outside the active plane of the device and must be connected by such a 90° bend. Furthermore, due to the placement of the waveguide, the means of lateral optical confinement are limited to real index guiding (via material regrowth) and effective index guiding (such as via a rib or ridge waveguide). In contrast, the current specification discloses a waveguide that 1) uses DBR mirrors to form the cladding layers (referred to in the specification as *effective cladding layers*), 2) is formed within the active plane of the device, and 3) does not require coupling by bending of the light. Finally the invented waveguide can be formed by gain/loss modulation and/or resonant wavelength modulation <u>in addition to</u> index modulation and effective index modulation. Given the fundamentally different and novel nature of the active waveguide (cladding material, placement, and coupling), all potential means of forming the lateral (x) waveguide should be allowed. Applicant believes claim 3 overcomes Abeles and is in condition for allowance, which is respectfully requested.

With respect to dependent claim 8, applicant reiterates the arguments made against rejection of claim 7, and dependent claim 2, because Abeles does not show, teach or suggest the forming of the discrete traveling photonic waveguide and optical tap of the present invention. Moreover, given the fundamentally different and novel nature of the waveguide, all potential means of extracting the light should be allowed, including an

etched facet. Applicant believes claim 8 overcomes Abeles and is in condition for allowance, which is respectfully requested.

With respect to claim 11, applicant reiterates the arguments made against rejection of claim 7 because Abeles does not show, teach or suggest the forming of the discrete traveling photonic waveguide. Moreover, given the fundamentally different and novel nature of the active waveguide (cladding material, placement, and coupling), all potential means of forming the lateral (x) waveguide should be allowed. Applicant believes claim 11 overcomes Abeles and is in condition for allowance, which is respectfully requested.

With respect to dependent claim 14, applicant reiterates the arguments made against rejection of claim 13. Abeles discloses a waveguide wherein the cladding layers comprise single, homogeneous material layers. In contrast applicant's invention using a passive waveguide with a significant portion of at least one cladding layer comprised of a DBR mirror or, *both* cladding layers may be *completely* composed of DBR mirrors. Next, Abeles' passive waveguide is specified strictly to be disposed on the surface, that is, as the last semiconductor layers of the device (See FIG. 4. layers 303, FIG. 3 layers 301 & 302). According to applicant's invention, the passive waveguide can be placed at the surface or, more advantageously, in the top or bottom mirror forming the vertical waveguide. Also, in contrast to Abeles, the current invention specifies that all light propagation and all coupling between active and passive waveguides occur in a co-planar fashion, that is, the light propagates in parallel planes before, during, and after coupling. Given the fundamentally different and novel nature of the passive waveguide (cladding material, placement, and

coupling), all potential photonic integrated circuits formed from the passive waveguide should be allowed. Finally, given the fundamentally different and novel nature of the active waveguide (cladding material, placement, and coupling), all potential passive waveguides coupled to it should be allowed. Applicant believes claim 14 overcomes Abeles and is in condition for allowance, which is respectfully requested.

With respect to dependent claim 15, applicant reiterates the arguments made against rejection of claim 13. Given the fundamentally different and novel nature of the active and passive waveguides of the current invention (cladding material, placement, and coupling), and the fundamentally different and novel nature of the photonic integrated circuits that they enable (monolithic growth, ease of wavelength selection, low coupling losses, widest possible array of discrete functions, medium to large scale integration, high integrated performance, low cost, etc.), all potential means of coupling from one component to another should be allowed. Applicant believes claim 15 overcomes Abeles and is in condition for allowance, which is respectfully requested.

Claims 4 and 6 stand rejected under 35 U.S.C. §102(e) on the basis of Kinoshita (US 6,535,537).

Claims 4 and 6, dependent from independent claim 1 as amended, avoid anticipation under the Kinoshita (US 6,535,537) reference. With respect to the rejection of claim 4, "Radial direction" is understood to mean a direction that is consistent with radial coordinates (r, θ, z), and such limitation is set forth in the claims. Moreover, Applicant finds no suggestion, teaching or disclosure in Kinoshita of a radial DFB grating. Applicant assumes "radial direction" to mean longitudinal (z) direction as defined in the current

specification for the following response.

Kinoshita discloses a waveguide capable of emitting radiation mode light in upper and lower directions. (Col. 1, ll. 49-50) Kinoshita discloses the only types of holograms that provide significant scattering of a horizontally guided mode into a radiated mode are of order 2 or higher. 1st or fundamental order holograms do not scatter light out of the plane of the waveguide (Col. 7, ll. 46-47), rather they efficiently provide feedback to forward and reverse traveling waves within the waveguide. Therefore, Kinoshita's hologram is restricted to a 2nd (or higher) order grating or, to paraphrase Kinoshita, "complex index of refraction or reflection." (Col 2, ll. 23-24 Simply, if a first order hologram were to be utilized in Kinoshita, the device of Kinoshita would not work. In complete contrast, applicant's invention utilizes a first order grating (or hologram) in the longitudinal or radial directions. Moreover, a second order grating, due to its lossy nature, would not be likely to work efficiently in the current invention.

Kinoshita also teaches a device with two distinct optical modes, a guided mode contained within the DFB waveguide, and a radiation mode propagating perpendicular to the waveguide (*See e.g.* Col. 1, ll. 47-57, Col. 2 ll. 7-17, 67 and numerous other locations throughout). These two modes are coupled via the 2nd order grating.. In contrast, applicant's invention discloses a single optical mode device wherein said single mode has a substantially mixed *k*-vector, as referred to in the art. In the parlance of Kinoshita, the mode may be thought of as coincidentally guided and radiated in nature. This is not to say that higher order modes could not be supported by the same cavity. Rather, it is to say that each optical mode is of mixed type and interacts with both DFB and

DBR simultaneously and not sequentially. Also it is clear that a conventional DFB waveguide is used insofar as the wavelength of the light propagating within it is determined solely by the periodicity of the hologram (*See e.g.* Col. 1, ll.48, Col. 2, ll. 43-44, and Col. 7, ll. 32-42 (as well other locations throughout)). In Applicant's invention, the wavelength of the light is determined substantially by the waveguide and feedback mechanisms in all three dimensions (*see e.g.* page 8, ll. 1-15). In particular, the resonator wavelength is determined principally by the DBR and DFB elements acting in concert (see example, pages 8-9 lines 16-5).

As a result, Applicant's invention discloses a device comprising a 1st order DFB grating, a single optical mode, and wavelength selection provided by the interaction between DBR and DFB elements. In contrast, Kinoshita suggests, teaches and discloses a device comprising a DFB hologram of order 2 or higher, with two distinct optical modes, and with wavelength selection provided by the DFB hologram and not by the DBRs. Given the fundamentally different and novel nature of the PWSE laser and its derivatives, claim Applicant believes claim 4 overcomes Kinoshita and is in condition for allowance, which is respectfully requested.

With respect to claim 6, Applicant renews the arguments made against rejection of claims 4 & 7. Applicant finds no suggestion, teaching or disclosure in the reference to the method of optical tap formation as set forth in the claim or is there any suggestion, teaching or disclosure found in the art of record so as to form the device of Kinoshita (US 6,535,537) as such device merely describes placing a second order DFB grating throughout a conventional horizontal waveguide and adding DBR mirrors above

and below to reduce radiation losses in an effort to address some of the difficulties with etched facets and integration. Moreover, Kinoshita has disadvantages of increased expense, increased design complexity, and a poor far-field pattern. Kinoshita essentially creates a coupled-mode device that suffers from problems relating to coupling and phasing between modes, whereby such problems need be managed carefully in order for the device to operate at all. Furthermore, the output of the Kinoshita coupled-mode device will invariably be multi-lobed as the 2^{nd} order grating that produces a null in the intensity profile for every half wavelength of light in the material (approximately every 110 nm at 1.55 μm). It is known that multi-lobed, non-Gaussian beams are difficult to couple into optical fibers. Fundamentally differences in the structure of the PWSE laser and of the active waveguide (cladding material, placement, and coupling), all potential means of forming the lateral (*x*) waveguide should be allowed. For the above reasons relating to Kinoshita, including those made regarding Claim 4, and in view of the discussion of the Abeles, Applicant's invention set forth in claim 6 is patentable over the art of record.

The structure of forming an integral distributed feedback grating to the cavity in the vertical (y) direction of present invention overcomes the disadvantages of the Abeles and Kinoshita references. As a result, the present invention provides a novel structure to address the problems associated with the current devices of the art, and applicant's invention enables photonic integration. Subsets of the laser device structure can be selected to create a variety of optical devices, such as tuners, combiners, splitter, mixers, switches, active or passive waveguides, narrow or broadband filters, electro-optic or electro-absorption modulators, amplifiers and photo detectors. In short, all the functions of

a photonic circuit can be integrated more easily due to the commonality of structural elements that make up each device

Claim 5 stands rejected under 35 U.S.C. §103(a) on the basis of Kinoshita (US 6,535,537).

Applicant reiterates the arguments made against rejection of claim 4. Applicant finds no suggestion, teaching or disclosure in Kinoshita (US 6,535,537) for optical tap formation as set forth in the claim 5 or is there any suggestion, teaching or disclosure found in the art of record so as to form the output/feedback etched gratings. The examiner points to the obviousness of forming the optical tap using etching as reason for rejecting this claim; however, applicant finds no implicit suggestion or teaching in Kinoshita. Applicant finds the recitation of "light output from gratings" as unclear in this regard and applicant's response the meaning to refer to the words "optical tap" in claim 5. Applicant submits that, given the fundamentally different and novel nature of the PWSE laser and its derivatives, all potential means of extracting useful light should be allowed without regard to how they are formed. For the above reasons relating to Kinoshita, including those made regarding Claim 4, and in view of the discussion of the Abeles, Applicant's invention is patentable over the art of record.

Claims 9 and 10 stand rejected under 35 U.S.C. §103(a) on the basis of Abeles in view of Kinoshita (US 6,330,265).

With respect to claim 9, applicant reiterates the arguments made against rejection of claim 7. Abeles neither teaches nor anticipates formation of an active

waveguide in the manner described in the current specification. Kinoshita's active waveguide (FIG. 22, element 203) guides the light perpendicular to the DBR, whereby Kinoshita's implementation of the DBR is conventional in the sense that light is reflected perpendicular to the DBR layers. No suggestion or teaching is provided how one would combine the optical confinement and feedback device of Abeles (taken to mean the oscillator portion of the device) with the active waveguide of Kinoshita. Where would it be placed? How would it be pumped separately from the oscillator? However, in contrast, as described in the specification of the present invention, light propagates parallel to the DBR and the idea that a DBR can be used to guide light parallel to the DBR layers is unconventional, non-obvious, and the resulting device would have a very different layer structure and mode of operation than the active waveguide of the current specification the active waveguide as set forth in applicant's specification. Applicant's invention could not have been constructed from elements of Abeles and Kinoshita without undue experimentation. For the above reasons relating to Abeles, and in view of the discussion of the Kinoshita, Applicant's invention is patentable over the art of record.

With respect to claim 10, applicant has cancelled claim 10 and combined the elements in claim 9. However, as to those elements applicant reiterates the arguments made against rejection of claim 7. The examiner argues that Kinoshita teaches a splitter that could be combined with Abeles to anticipate the splitter of applicant's invention. The Kinoshita device combines the function of a splitter (single input, multiple outputs) with that of a filter (wavelength selectivity). No wavelength selectivity is specified, that is, the splitting function does not necessarily include a filtering function. The device, as

specified, could not be used as a simple splitter because there are multiple grating wavelengths present. Applicant's splitter is defined as a device that splits light from a single waveguide into two or more separate waveguides. *See* page 37 lines 8-9. Moreover, the splitter of Claim #10 does not "filter out unnecessary frequencies and further refine the output signal to a desired wavelength." It is a simple power splitter. No suggestion or teaching is provided how one would combine the optical confinement and feedback device of Abeles (taken to mean the oscillator portion of the device) with the splitter of Kinoshita. Furthermore, it is not clear to the author exactly how one would combine the optical confinement and feedback device of Abeles (taken to mean the oscillator portion of the device) with the splitter of Kinoshita. Where would it be placed? How would it be pumped separately from the oscillator? In any case, the resulting device would have a very different layer structure and mode of operation than the splitter of the current specification. Applicant submits the combination could not have been constructed from elements of Abeles and Kinoshita without undue experimentation. For the above reasons relating to Abeles, and in view of the discussion of the Kinoshita, Applicant's invention is patentable over the art of record.

For the foregoing reasons, applicants believe that this case is in condition for allowance, which is respectfully requested. The examiner should call applicants' attorney if an interview would expedite prosecution.

Respectfully submitted,

INTELLECTUAL PROPERTY ADVISORS LLC

By [signature]
Damian G. Wasserbauer
Registration No. 34,749

November 7, 2005

PO Box 156
Canton, CT 06019
Telephone: 860.966.0989
Facsimile: 860.693.1674
Customer No. 36601